Opinion Paper

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Radiology education: a radiology curriculum for all medical students?

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Abstract: Diagnostic errors in radiology are frequent and can cause severe patient harm. Despite large performance differences between radiologists and non-radiology physicians, the latter often interpret medical images because electronic health records make images available throughout the hospital. Some people argue that non-radiologists should not diagnose medical images at all, and that medical school should focus on teaching ordering skills instead of image interpretation skills. We agree that teaching ordering skills is crucial as most physicians will need to order medical images in their professional life. However, we argue that the availability of medical images is so ubiquitous that it is important that non-radiologists are also trained in the basics of medical image interpretation and, additionally in recognizing when radiological consultancy should be sought. In acute situations, basic image interpretations skills can be lifesaving. We plead for a radiology curriculum for all medical students. This should include the interpretation of common abnormalities on chest and skeletal radiographs and a basic distinction of normal from abnormal images. Furthermore, substantial attention should be given to the correct ordering of radiological images. Finally, it is critical that students are trained in deciding when to consult a radiologist.

Keywords: diagnostic error; image interpretation; medical education; radiology.

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Background

Diagnostic errors are frequent and can cause severe patient harm [1]. A substantial number of those errors occur in radiology [2]. In 1949, Henry Garland shocked the radiology world by presenting unexpectedly high diagnostic error rates in radiology. He found that 30% of the abnormalities in chest radiographs were missed and the false alarm rate was 2% [3]. Surprisingly, in studies that have been conducted since then, the error rates have remained stable [4]. This does not mean that in contemporary medicine these missed abnormalities are of the same type and severity as in 1949 because newly developed techniques and improved image quality enable radiologists to detect smaller, more subtle and even previously undetectable abnormalities.

The error rates of non-radiology physicians are – not surprisingly – substantially higher than those of radiologists [5, 6]. Potchen and colleagues [5] showed that when three groups of physicians (radiologists, radiology residents and non-radiology physicians) were asked to diagnose a standardized set of 60 chest X-rays, the certified radiologists outperformed the radiology residents and the residents performed better than the non-radiologists physicians. Eng et al. [6] found similar results when comparing emergency medicine physicians and emergency medicine residents to radiologists and radiology residents.

Despite the large difference between radiologists and non-radiology physicians in diagnostic performance, the access to medical images in the electronic health records is not limited to radiologists. Non-radiology physicians, for example, at the emergency department, on the internal medicine or surgical wards, also have access to the medical images of their patients. These non-radiology-physicians (including relatively inexperienced residents) are often expected to interpret medical images before the radiologists see them [7]. Consequently, treatment decisions or further diagnostic testing takes place based on interpretation of non-radiology physicians. The question is whether this is desirable: a recent review on radiology education in Europe revealed that the amount of hands-on

image interpretation practice in some countries is as low as 1 h in medical school [8]. In the United States, the amount of radiology education is also limited [7]. On top of that, there is very little attention for appropriate ordering of medical images in medical school [8]. Particularly now, the growing number of options in medical imaging and the increasing complexity of the imaging techniques make it more difficult to select the right imaging technique. Some experts suggest to focus radiology education in the undergraduate curriculum on ordering the medical images and reduce the amount of education of hands-on image interpretation skills [9].

The central question in this article is 'How should radiology education in the undergraduate curriculum be organized to prepare medical students for their future profession?' To answer this question, we discuss (1) the importance of teaching image interpretation, (2) the importance of teaching appropriate ordering of medical imaging, (3) how these two objectives relate to prospective clinical practice and how to prioritize those in a curriculum and (4) recommendations for an undergraduate radiology curriculum.

Importance of teaching image interpretation skills

The digitalization of radiological images and the introduction of the picture archiving and communication systems improved the availability of medical images throughout the hospital. Access to medical images of patients is no longer limited to radiologists. Non-radiology physicians interpret medical images and base their treatment and follow-up diagnostics on their own interpretation [7]. No guidelines exist about the extent to which non-radiologists are entitled to interpret images, or whether they should always consult a radiologist is. Although there is no agreement among experts, we feel that having non-radiologist interpret images can potentially contribute to better safety outcomes in clinical practice if the physician is able to identify diseases that require immediate action. For example, a patient presents at the emergency department with severe shortness of breath. A chest X-ray is obtained and immediately available. A pneumothorax is directly identified by the emergency doctor, and the treatment can start right away. Research shows that this scenario is likely to happen in practice. Almost all non-radiology residents in hospitals are expected to read medical images, and 30.7% of the residents are asked to do so several times a day [7]. Many medical specialists use medical images for surgery planning and evaluation, understanding the extensiveness of a disease, or for explaining patients their medical condition. Moreover, patients are able to view their own images via the electronic portals in a growing number of hospitals, necessitating non-radiologist to discuss medical images with their patients. Image interpretation and use of images are no longer reserved for radiologists. It requires education focused on hands-on interpretation skills to decrease the error rate of (junior) non-radiology physicians.

Importantly, it is been found in many tasks that novices in that task are more likely to overestimate their own performance in the task [10]. More training in a task is found to decrease overestimation. Thus, we argue that training non-radiologists in interpretation skills is likely to have a desirable side effect of decreasing overestimation. That, in turn, makes it likely that non-radiologists are more aware in which cases immediate consultation of a radiologist is required.

Thus, better trained non-radiologist could contribute to better understanding when immediate consultation of a radiologist is required and therefore potentially lead to faster diagnosis and treatment.

The importance of teaching appropriate ordering of medical imaging

Radiology is a medical specialty that is chosen by a small percentage (approximately 5%) of the medical students, but also only a small group of students will never be involved with medical imaging in their profession. Most medical students will be ordering medical images at some point in their career. Many problems and inefficiencies can arise from incorrect ordering, e.g. when images are ordered that cannot answer the question at hand, when an imaging technique is not appropriate for a specific patient or when imaging is not indicated, for example, if the result does not alter treatment decisions. Besides, there are many safety issues related to medical imaging, such as contraindications and risks. For example, an MRI scan may not be a safe option for a patient with a pacemaker. Risks of imaging techniques include allergic reactions to contrast material, renal failure and radiation risks. Incorrect or suboptimal orders of imaging result in substantial costs and patient harm. Therefore, radiology education in the undergraduate curriculum should also include knowledge and skills that are necessary for ordering the correct

images, such as indications and contraindications for imaging and risks and side effects of imaging.

Additionally, non-radiology physicians need to learn about the structure and interpretation of radiology reports. An incorrect interpretation of a radiology report can have serious consequences.

To summarize, the undergraduate curriculum should pay attention to the skills a non-radiology physician needs to effectively select and request medical images and to correctly interpret the results.

How these two objectives relate to prospective clinical practice and how to prioritize those in a curriculum

The curriculum in medical school is already packed, and choices have to be made on what to teach and what not to teach. The time available for radiology education should focus on those aspects that are relevant to the future specialties of medical students. Some authors advocate that medical students should exclusively learn how to order images correctly and should be discouraged from interpreting images because their level of accuracy would not come close to that of radiologists [9]. This brings us to the question whether medical images should be interpreted by non-radiology physicians or whether this should be exclusively done by radiologists. We are convinced that medical students should be trained to recognize abnormalities that are common or require immediate treatment or additional imaging. Specifically, this is particularly necessary for radiographs because they are often seen by clinicians before the radiological report is available.

As long as the images are available for all doctors in the hospital, the non-radiologists will interpret them. The availability of images inside and maybe even outside the hospital will only further expand in the future – in some institutes the images are even available for patients at home. Non-radiologists must therefore be able to explain the imaging finding to their patients. This further broadens the need for expertise of non-radiologists to at least understand imaging findings even for other imaging techniques, e.g. CT and MRI. We should embrace this development, and we are therefore convinced that the total amount of radiology education in the undergraduate curriculum should be increased. The contribution of imaging to medical diagnosis is increasing [11, 12], and radiology is getting a more central role in medicine. Education focused on teaching basic image interpretation skills and appropriate ordering medical images are both very important in contemporary medicine.

As was mentioned before, the medical curriculum is already packed so adding lectures and training sessions to the curriculum should be justified. In light of what will be most relevant to all medical students, education should focus on the most common and acute types of images they will encounter, i.e. chest and skeletal X-rays. Indeed, both clinicians and students consider these to be important topics in undergraduate radiology curricula [13–15]. These are the types of exams most often encountered by non-radiologists. The most common diseases such as pneumonia, heart failure, pneumothorax, fractures and subluxations should be the focus of the education. Importantly, recognizing normal images and the effect of image quality (e.g. a seemingly enlarged heart when the image is taken from an oblique angle) should also be included.

Concerning the ordering skills, it is not realistic to expect clinicians to fully understand all available options, but they are often expected to order the medical images without the involvement of a radiologist [7]. The ACR appropriateness criteria (see https://acsearch.acr.org/list) may be used to assist in making an adequate choice. In complex cases, ordering medical images should be done in collaboration with radiologists and should not be the sole responsibility of non-radiology physicians. Therefore, undergraduate education should focus on basic ordering skills that assists students in ordering the most used imaging modalities, such as X-rays, ultrasound, CT and MRI, for common diseases. In clinical practice, the more complex cases can be discussed with radiologists. Furthermore, students should be trained in more general principles for ordering and radiation safety and should be aware of regulations such as the ALARA principle. There is an ongoing trend towards a more prominent role for the radiologists in the diagnostic team. This was also mentioned in a recent influential report from the Institute of Medicine called ‘improving diagnosis in health care’ and in recent paper about reducing diagnostic errors [16, 17]. For example, the participation of radiologists in multidisciplinary meetings is crucial. In the capacity as a member of the diagnostic team, radiologists can contribute to selecting the correct imaging technique and the interpretation of the findings for a specific clinical situation.

To summarize, medical students should know the properties, contraindications and purpose of the most important imaging techniques, and they should be able to interpret the most common as well as the acute

diseases that require immediate treatment. However, as soon as a case goes beyond the standard approach, radiologists should be consulted to discuss a patient. This will also be helpful for the radiologists because this enables them to interpret images in the clinical context of a patient.

Consulting a radiologist in complex cases requires that a physician is aware of the complexity of a case. However, it is widely found that knowing the limits of your own knowledge is hard [18], and this is particularly true for novices in a domain [10, 19]. Allowing non-radiology physicians to read medical images may result in overconfidence, which may prevent them from asking for help. Overconfidence is a typical cause of diagnostic error, also in experts [20], and occurs when non-radiology physicians overestimate their ability to read medical images. Therefore, it is important to give students a sense of the breadth and complexity of image interpretation and emphasize that image interpretation is a very difficult task [9]. Additionally, it should be stressed that radiologists are available for consultations at any time.

Recommendations for an undergraduate radiology curriculum

First of all, it is critical that radiology education is integrated in the curriculum (see Collins et al. [21] for an example of an integrated longitudinal radiology curriculum). Radiological images are used more and more for teaching anatomy [22, 23], and this helps students to gain familiarity with radiographs. Most importantly, however, if students have to learn to interpret radiological images, image interpretation needs to be part of the curriculum, and radiology should not be taught in lectures only: practicing with a substantial number of real-world cases promotes learning [24]. E-learning modules are widely used in radiology because they provide great opportunities for practicing interpretation skills with (immediate) feedback [25–27]. They allow for practicing the whole task of image perception, interpretation and decision [28] and provide scaffolding of the task. Importantly, teaching files should include not only abnormal radiographs but also normal images of different image quality. Detailed recommendations for designing effective and efficient instruction in radiology can be found elsewhere [25].

Interestingly, both clinicians and students consider 'developing a system for viewing chest radiographs' to be important [13, 14], although recent research could not establish evidence for the effectiveness of teaching systematic viewing [29, 30].

We argued before that non-radiologists should consult radiologists when appropriate. Being able to judge when a case is too complex requires practice too, and we recommend that e-learning modules also include opportunities for practicing this judgment, for example, by provide the option to 'consult a radiologist', and provide feedback on the appropriate use of this option.

Finally, high-quality, authentic assessment of radiological interpretation skills is critical [31]. For testing image interpretation, high-level cognitive processes such as application and synthesis [32] can be tested by simulating the task with image questions. Ideally, questions include a radiological image, accompanied by a short patient vignette. To simulate the image interpretation process, questions could include marking abnormalities (perception), describing abnormalities (analysis) and rendering differential diagnoses (synthesis) [28]. Because the visual component is key, the quality of images should receive much attention. The representation and quality of images can seriously affect the ability to detect an abnormality [33]. Unfortunately, the computers used in medical education in general do not meet the standards of radiology practice, but incorporating possibilities for image manipulation such as zooming and adapting contrast settings can improve perceived image quality and authenticity.

In conclusion, we argue for a radiology curriculum for all medical students: clear guidelines as to what diagnostic decisions non-radiologists should be able to make, as well as training and assessment that are aligned with these guidelines. This should include basic chest and skeletal radiograph interpretation. Although students should receive training in interpreting the basic abnormalities and distinguishing normal from abnormal cases, a critical aspect of radiograph interpretation should be the ability to distinguish between cases that can be resolved by non-radiologists, and cases where radiological consultation should be sought. Finally, students should be thoroughly trained in ordering medical images. Such a radiology curriculum could impact error rates throughout the hospital and beyond.

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